UNIVERSITY

Chapter (1)

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Ideal Gas

SI Units

Constant	Symbol	Value in SI Units	Value in c.g.s units
Avogadro's constant	N_A	6.022×10^{23} mol^{-1}	6.022×10^{23} mol^{-1}
Planck's constant	h	6.026×10^{-34} J s	6.026×10^{-27} erg s
Boltzmann constant	K	1.3806×10^{-23} J K^{-1}	1.3806×10^{-16} erg K^{-1}
Gas constant	R	8.3144 J K^{-1} mol^{-1} 0.082 L atm mol^{-1} K^{-1}	1.987 cal K^{-1} mol^{-1}
Atmospheric pressure	P	1.01325×10^{5} N m^{-2}	1 atm
Acceleration	g	9.80665 m s^{-2}	--
Gravitational constant	G	6.672×10^{-11} N m^{2} Kg^{-2}	--
Speed of light	c	2.9979×10^{8} m s^{-1}	2.9979×10^{10} cm s^{-1}

Important conversion factors

- 1cal = 4.184 J =4.184 x 10^{-7} erg = 41.293 atm cm^3
- 1 N = 10^5 dynes
- 1 J = 10^7 ergs = 0.239 cal
- 1 eV = 1.602 x 10^{-19} J = 1.6021 x 10^{-12} erg $molecule^{-1}$
- = 96.48 kJ mol^{-1} = 23.06 kcal mol^{-1}= 8065.5 cm^{-1}
- 1 atm = 760 mm Hg = 760 Torr = 101325 N m^{-2} = 101.325 kPa
- 1 bar = 10^5 Pa = 0.987 atm
- 1 L = 10^3 cm^3 = 1 dm^3
- 1A°= 10^{-8} cm = 10^{-10} m
- Kelvin = Tc° + 273

Ideal gas

Defined as

It is the gas in which the intermolecular interaction are very small and the volume occupy by the gas molecule is also very small comparing with the total volume of the gas and obey the gas law.

Laws of gases

1) Boyle's Law

Boyle's Law

$P_1V_1 = P_2V_2$

(T constant)

Which state that

" at constant temperature, the volume of any definite quantity of gas varied inversely proportional with pressure".

$$P \propto \frac{1}{V} \quad \text{(at constant temperature)}$$

PV = R (R is constant)

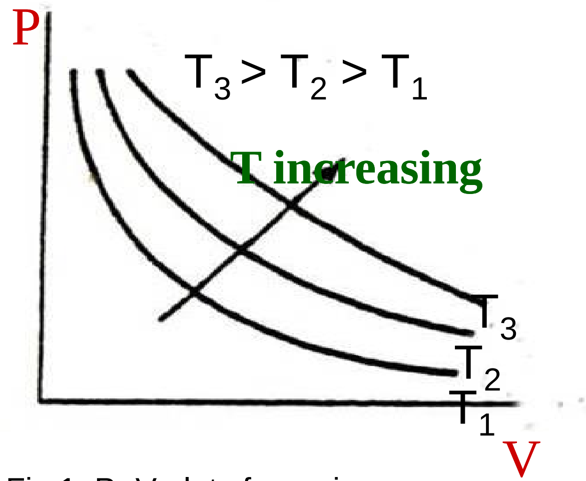


Fig.1 .P- V plots for a given amount of gas at three temperatures

For an isothermal process in which the initial value (P1, V1) are changed to value (P_2, V_2), Boyle's law write as follows:

P1V1 = P2V2

Laws of gases

2) Charle's Law

State that

"at constant pressure, the volume of definite quantity of the gas directly proportional with temperature".

$$V \propto T \quad \text{(at constant pressure)}$$

Charle's work was done for a gas at 0°C (To) and Vo, and at T °C and V then, according to this law,

$$V = Vo\,(1 + \alpha T)$$

V = Volume at any temperature

Vo = Volume at 0°C temperature

T = Centigrade temperature(t) + 273

- α = Expansion per degree and its value = (1/273)

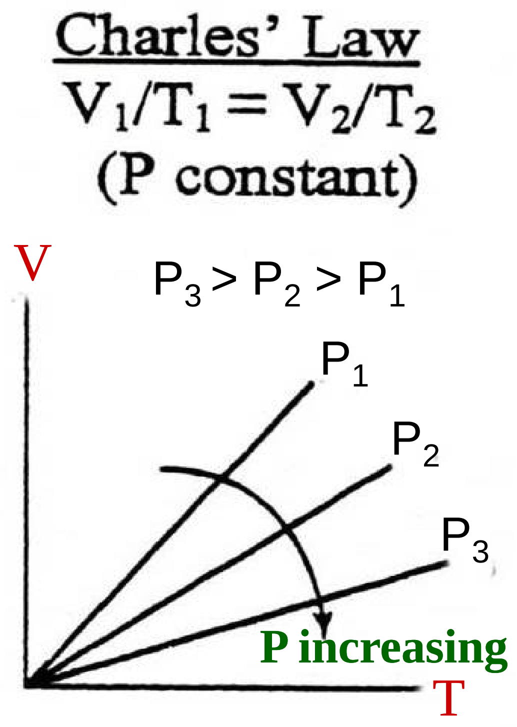


Fig.2 . V-T plots for a given amount of gas at three pressures

Example

one mole of an ideal gas accupies a volume of $0.144 \times 10^{-3}\ m^3$ at 290.16 K and 1 atm. The gas is heated to 1160.64 K at constant pressure.

Calculate the volume accupied by the gas.

Answer = $0.576 \times 10^{-3}\ m^3$

Laws of gases

3) Combine gas Law

a) According to Boyle's Law

$$P \propto \frac{1}{V} \quad \text{(at constant temperature)}$$

b) According to Charle's Law

$$V \propto T \qquad \text{(at constant pressure)}$$

Combining of both laws will be

$$V \propto \frac{T}{P}$$

$$V = R\frac{T}{P}$$

$$PV = RT$$

Above equation represents the behavior of an ideal gas, for one mole of a gas.

If 'n' moles are taken then,

PV = nRT

Example

As one mole of an ideal gas accupies a volume 22.414 L at N.T.P (0°C and 1 atm), find value of R in J K^{-1} mol^{-1} and atm L K^{-1} mol^{-1} (in c.g.s ans SI unit)

Answers:

R= 8.314 J K^{-1} mol^{-1}

R = 0.082 atm L K^{-1} mol^{-1}

4) Gay-Lussac Law

State that

"at constant volume, the pressure of definite quantity of the gas directly proportional with temperature".

$$P \propto T$$

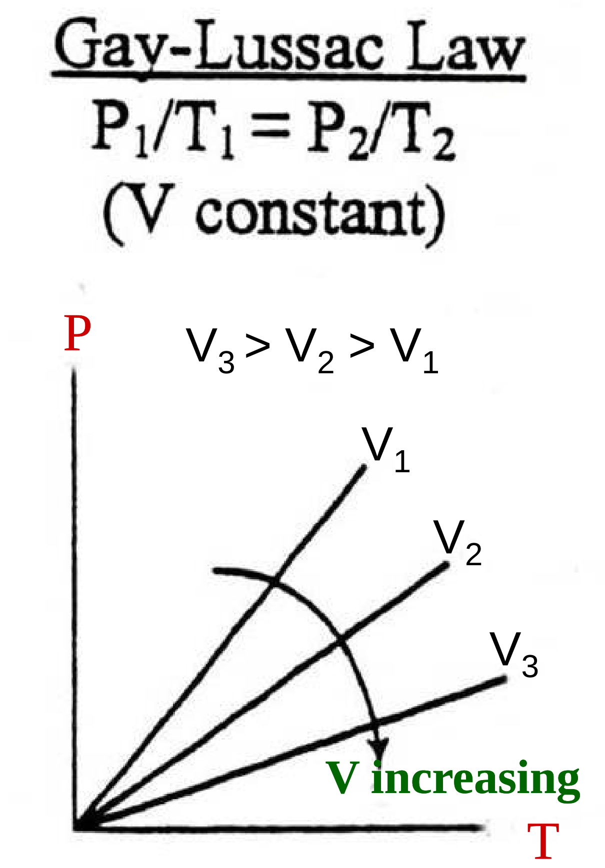


Fig.3 . P-T plots for a given amount of gas at three volumes

5) Dalton's Law

State that
"at constant temperature, the sum of the partial pressures equals the pressure of the gas phase".

Dalton's law applying on the mixture of the gas under one condition there must be no reaction take place between gases.

$Pt = \Sigma Pi$

Pt = total of partial pressure

Pi = partial pressure of substance and i in mixture of gases.

For ideal gas mixture

$$Pt = \frac{nRT}{V}$$

$Pi = Ni\ Pt$ where Ni is mole fraction

Laws of gases

6) Graham's Law of Diffusion

Which state that

"the rate of diffusion of a gas is inversely proportional to the square root of the density of the gas at constant pressure".

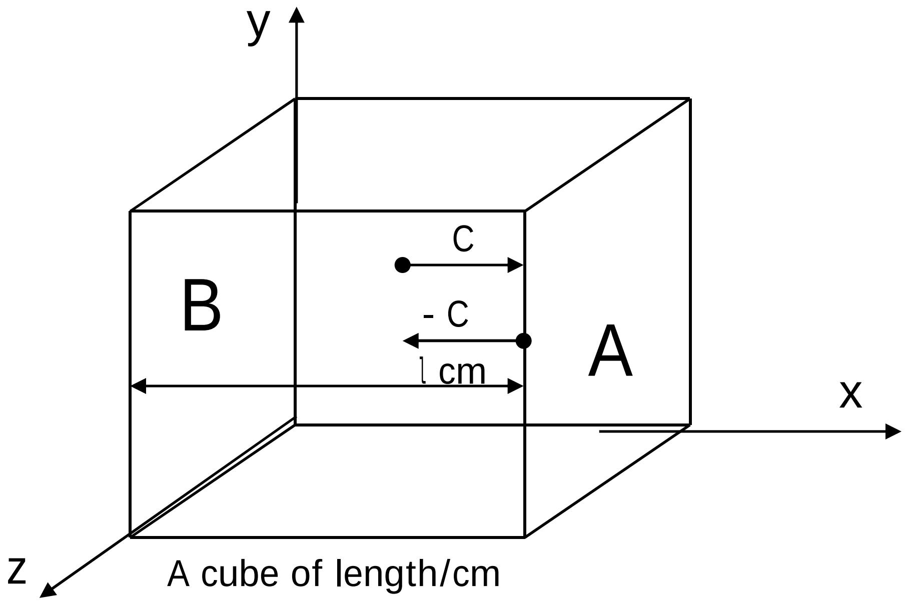
$r \propto (1/d)^{1/2}$

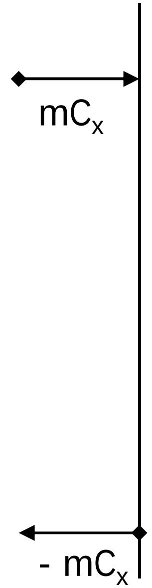
$$\frac{v_1}{v_2} = \left(\frac{d_2}{d_1}\right)^{1/2} = \left(\frac{m_2}{m_1}\right)^{1/2}$$

r = rate of diffusion of the gas, d = density of the gas, m = molecular mass of gas and v = vapour density of gas.

Vapour density is independent on temperature and has no unit whereas absolute density depends upon temperature and is unit expressed in g/L

Kinetic Theory of Gas





suppose a definite mass of a gas is contained in cubical vessel:

the length of each side of cube = l cm

the total number of molecules = N

the mass of molecules = m

the velocity of molecule = C

The momentum of the molecule before it strikes the wall in x-direction = mCx

The momentum of the molecule after it strikes the wall in x-direction = - mCx

Kinetic Theory of Gas

The change in momentum due to collision against the wall in container

$$= mC_x - (-\,mC_x) = 2mC_x$$

in order to strike the same wall A again, the molecule have to move in opposite wall B and come back. It mean that the particle has to travel a distance 2*l* cm for each successive collision.

The number of collision per second $= \dfrac{C_x}{2l}$

The change in momentum per second (due to $\dfrac{C_x}{2l}$ impact) on wall A

$$2mC_x \times \frac{C_x}{2l}$$

$$= \frac{mC^2_x}{l}$$

Total change in momentum per second because of collision of the molecule on two opposite wall A and B along x-axis is equal to

$$\frac{mC^2x}{l} + \frac{mC^2x}{l} = \frac{2\ mC^2x}{l}$$

therefore, the total change in momentum per second in all directions, is equal to

$$= \frac{2\ mC^2x}{l} + \frac{2\ mC^2y}{l} + \frac{2\ mC^2z}{l}$$

$$= \frac{2\ m}{l}(C^2x + C^2y + C^2z)$$

$$= \frac{2\ mC^2}{l}$$

Kinetic Theory of Gas

According to Newton's second law of motion, the rate of momentum is force

$$\text{Force} = \frac{2mC^2}{l}$$

The pressure 'P' (force per unit area) is the total force divided by area of six walls of cube

$$P = \frac{2mC^2}{l} \times \frac{1}{6\,l^2}$$

$$= \frac{mC^2}{3\,l^3}$$

But l^3 is the volume of the cube 'V'

$$P = \frac{mC^2}{3V}$$

$$PV = \frac{1}{3}\,mC^2$$

The kinetic gas equation for N particles is given by **$PV = 1/3\ m\ N\ C^2$**

Kinetic Energy

Kinetic Energy

$K.E = 1/2\ m\ C^2$

The kinetic energy per mole of the gas for N particles is given by

$K.E = 1/2\ m\ N\ C^2$

According to kinetic gas equation

$PV = 1/3\ m\ N\ C^2$

Multiply above equation by 2/2, we obtain

$PV = 2/3 \times 1/2\ m\ N\ C^2$

$PV = 2/3\ K.E$ $\qquad\qquad (PV = RT)$

$RT = 2/3\ K.E$

$$\boxed{K.E = 3/2\ RT}$$

Hence, $K.E \propto T$

Calculation of Heat Capacity of Gas (Cv, Cp)

i) Calculate Cv from kinetic theory of gas

$$Cv = (K.E)_2 - (K.E)_1$$

$$Cv = 3/2\ RT_2 - 3/2\ RT_1$$

$$= 3/2\ R(T_2 - T_1)$$

For Ideal gas will be

$$\mathbf{Cv = 3/2\ R}$$

Calculation of Heat Capacity of Gas (Cv, Cp)

ii) Calculate Cp from kinetic theory of gas

$$Cp - Cv = R$$

$$Cp = R + Cv$$

$$= R + 3/2\ R$$

$$\mathbf{Cp = 5/2\ R}$$

Examples on Ideal Gas

Example (1)

As one mole of an ideal gas accupies a volume 22.414 L at N.T.P (0°C and 1 atm), find value of R in J K^{-1} mol^{-1} and atm L K^{-1} mol^{-1} (in c.g.s ans SI unit)

Answers:

R= 8.314 J K^{-1} mol^{-1}

R = 0.082 atm L K^{-1} mol^{-1}

Example (2)

Calculate the pressure exerted by one mole of carbon dioxide gas in a 1.32 L vessel at 48°C

Example (3)

one mole of an ideal gas accupies a volume of $0.144 \times 10^{-3}\ m^3$ at 290.16 K and 1 atm. The gas is heated to 1160.64 K at constant pressure.

Calculate the volume accupied by the gas.

Answer = $0.576 \times 10^{-3}\ m^3$

Example (4)

an open vessel contains air at 27 °C. to what temperature should be vessel be heated so that no. of molecules in the vessel decreased by 25% (neglect the expansion of the container).

Answer = 127 °C

Example (5)

H.w

A balloon is inflated with air in a warm living room (24°C) to a volume of 2.5 L. it is taken out on a very cold winter's day (-30°C). Assuming pressure both remains constant. What will be the volume of the balloon when it is out doors?

Answer = 2.04545 L

Example (6)

A mixture consisting of 2.8 X 10^{-2} Kg of nitrogen and 6.4 x 10^{-2} Kg of oxygen. Accupies a volume 8.314 x 10^{-3} m^3 at 300K. calculate the mole fraction of each gas in mixture, their partial pressure and the total partial pressure exerted by the gaseous mixture.

Example (7)

A teacher enters a class-room from front door while a student from back door. There are 13 equidistance rows of benches in the class-room. The teacher releases N_2O gas, the laughing gas from the first bench while the student releases the weeping gas ($C_6H_{11}OBr$) from last bench. At which row will the student start laughing the weeping simultaneously?